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SPECS
Seasonal-to-decadal climate Prediction for the improvement of European Climate Services

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Centro Nacional de Supercomputación

WGSIP experience: land, ocean, cryosphere initialization

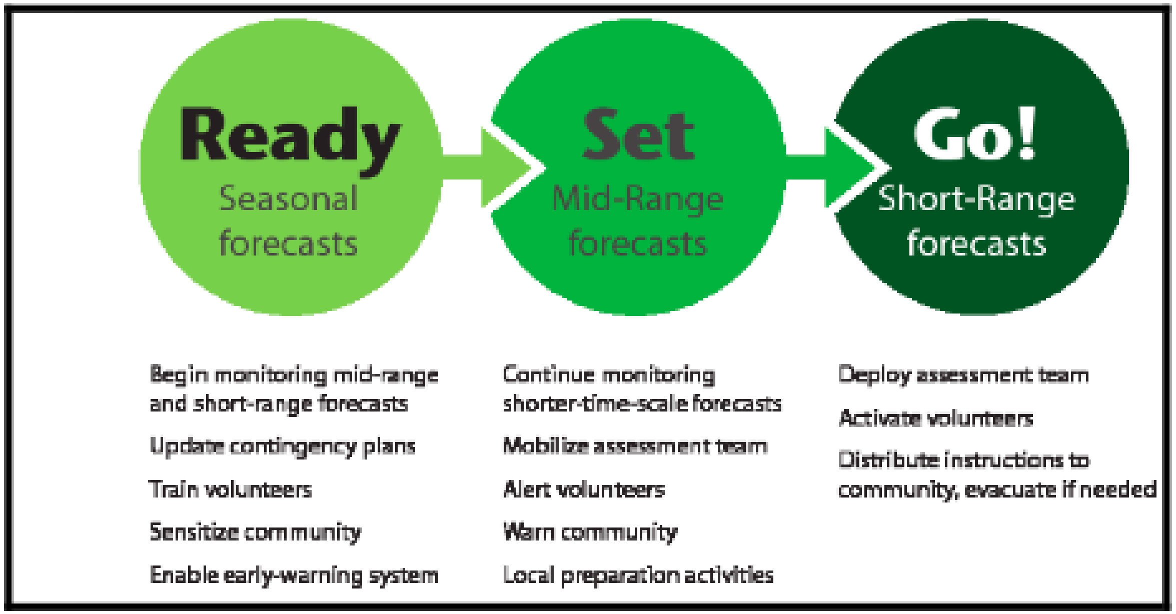
Francisco Doblas-Reyes

Paris, 10 March 2015

Seamless prediction, user driven

Application of seamless climate and weather information. Example from the IRI-Red Cross collaboration:

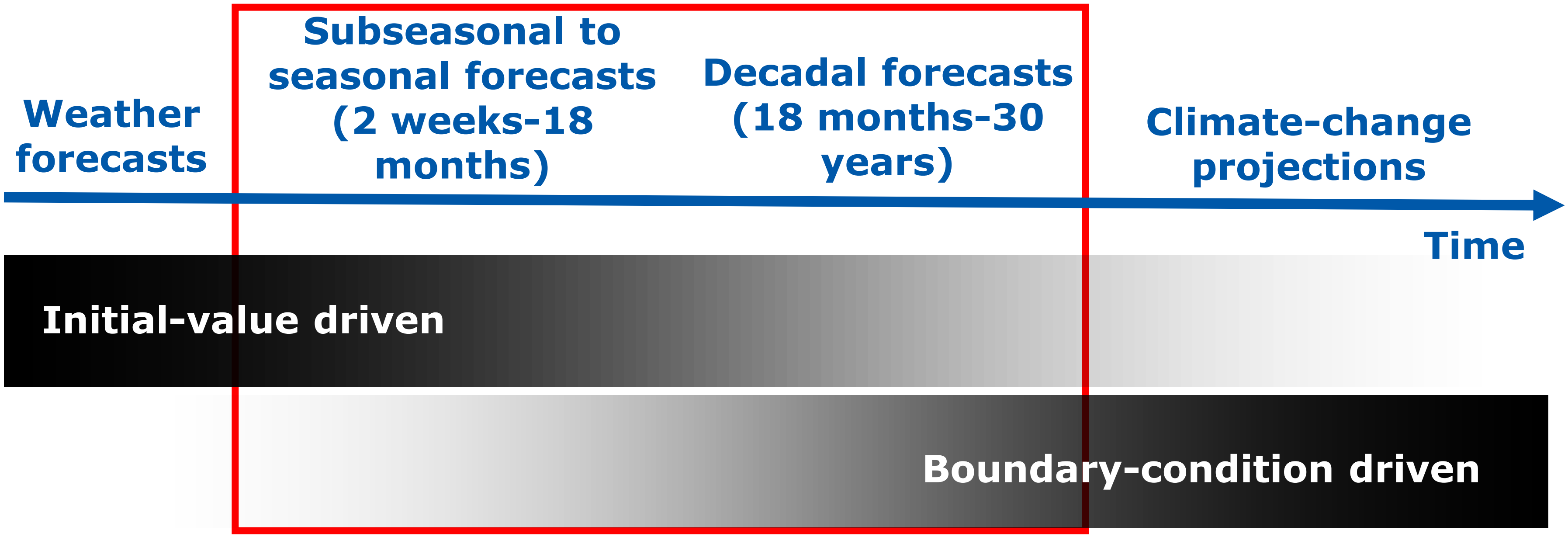
- Likelihood of severe, high-impact weather (drought, flooding, wind storms, etc.), humanitarian planning and response to disasters, agriculture (e.g. wheat and rice production), disease control (e.g. malaria, dengue and meningitis), river-flow (e.g. flood prediction, hydroelectric power generation and reservoir management).



IRI

Climate time scales and climate prediction

Progression from initial-value problems with weather forecasting at one end and multi-decadal to century projections as a forced boundary condition problem at the other, with climate prediction (sub-seasonal, seasonal and decadal) in the middle. Prediction involves initialization and systematic comparison with a simultaneous reference.



Adapted from Meehl et al. (2009)

Climate system predictability

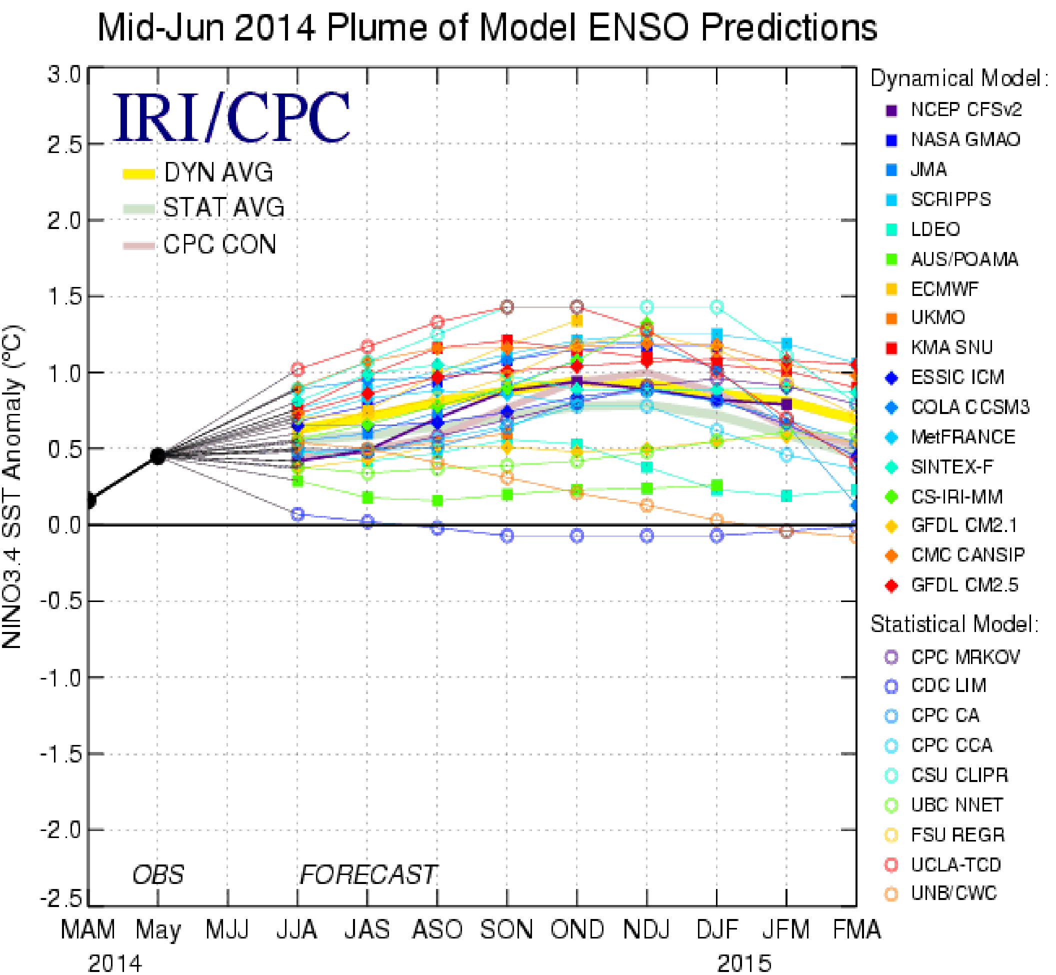
- Memory on interannual to centennial time scales in the **ocean**
- Memory on seasonal to interannual timescales in the **sea ice** and **land surface**
- External **radiative forcings** (solar activity, volcanoes, greenhouse gases, aerosols)

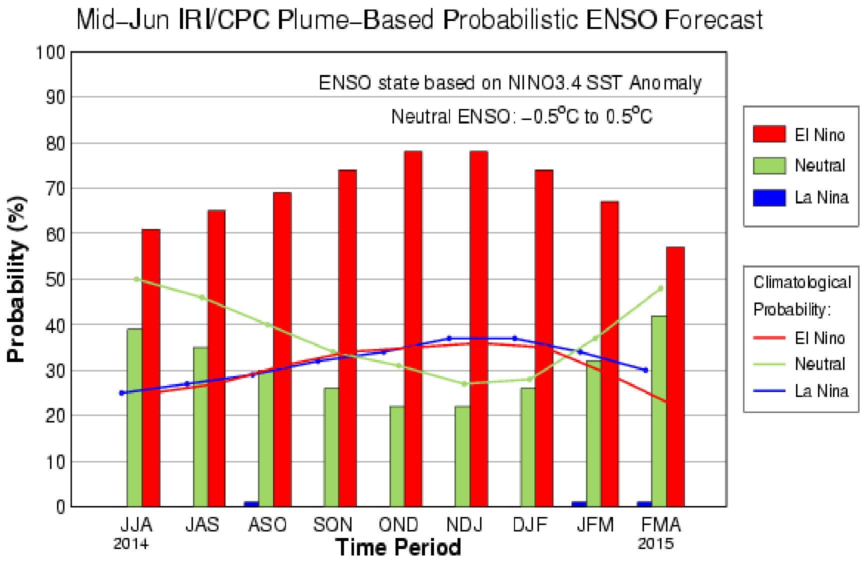
Some open fronts in climate prediction

- Work on initialisation: generate initial conditions (e.g. for sea ice, ocean). Compare different initialisation techniques (e.g. full field versus anomaly initialisation)
- Improving model processes: Inclusion and/or testing of model components (biogeochemistry, vegetation, aerosols, sea ice) or new parameterizations, model parameter calibration, increase in resolution
- Calibration and combination: empirical prediction (better use of current benchmarks), local knowledge
- Forecast quality assessment: scores closer to the user, reliability as a main target, process-based verification, attribution of climate events with successful predictions, diagnostics of model weaknesses with failing predictions
- More sensitivity to the users' needs: going beyond downscaling, better documentation (e.g. use the IPCC language), demonstration of value and outreach

Seasonal forecasts: a matter of communicating

2014 ENSO predictions: June start date





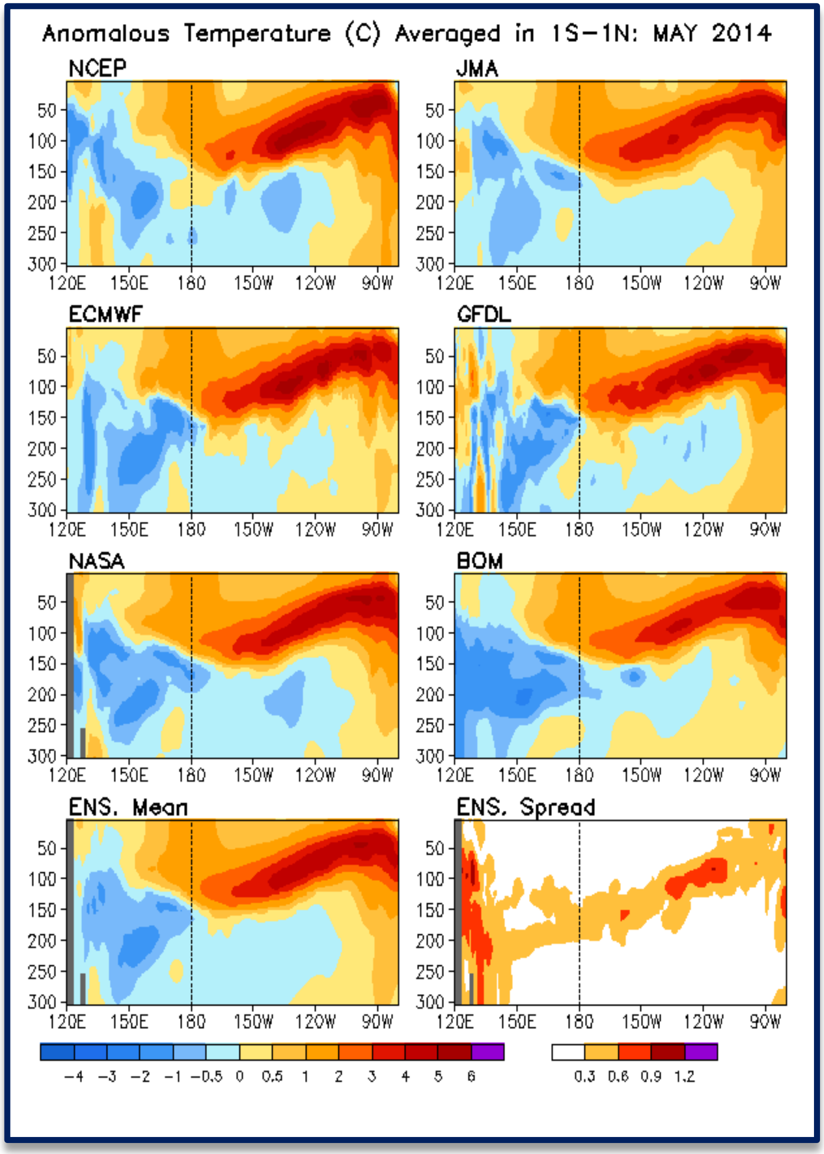
- Community effort
- Probabilistic character, lack of consistency
- Link to operations
- Communication issues

Initial conditions

Real-time ocean reanalysis comparison. Temperature anomalies along the Equator based on 1981-2010 climatology.

Large spread in real-time initial conditions (similar message from CLIVAR-GSOP).

Good observations of the whole system are absolutely fundamental for accurate predictions.



Y. Xue (CPC)

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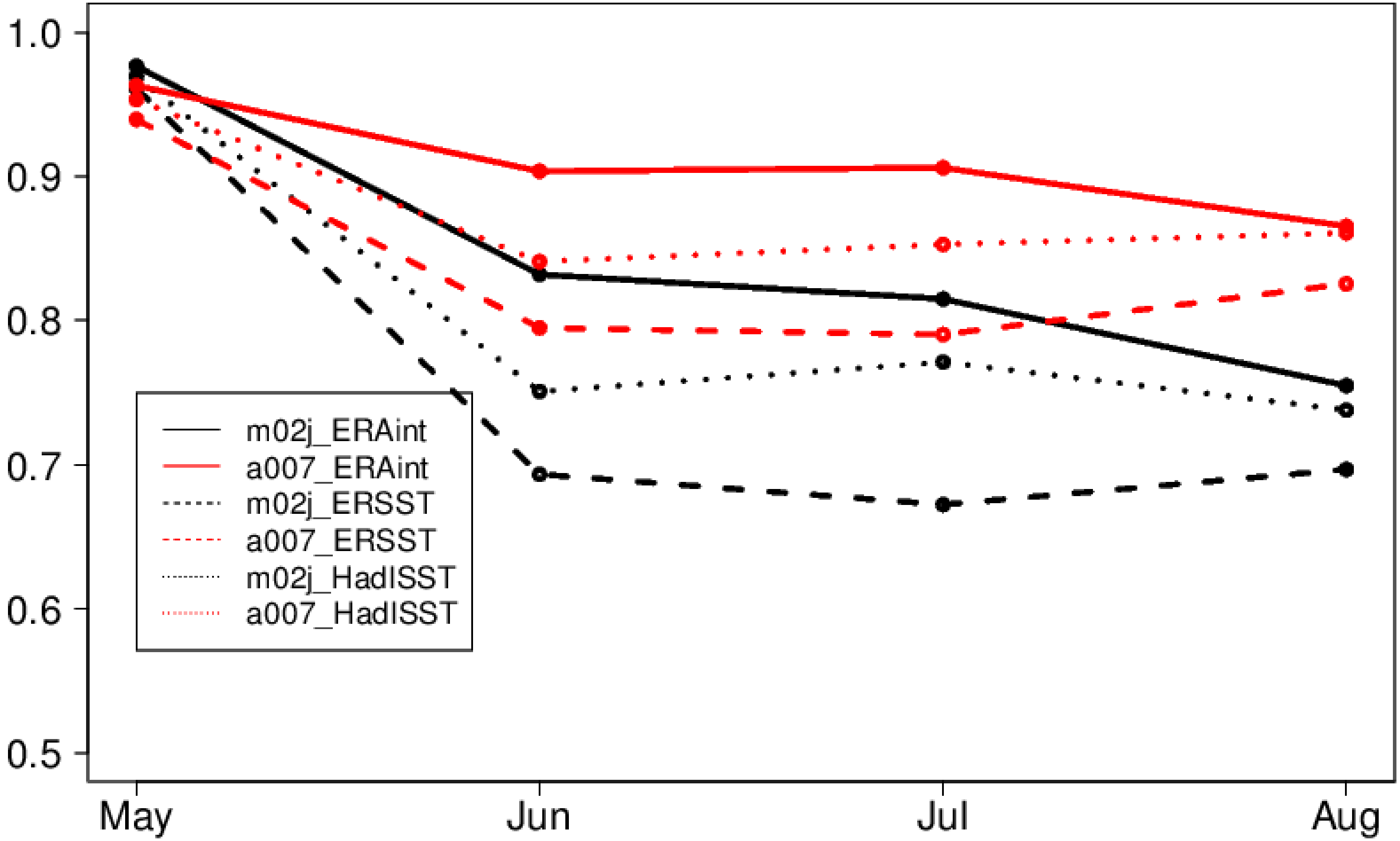
Initial conditions: ocean

Niño3.4 SST correlation of the ensemble mean for EC-Earth3.1 hindcasts started from ORA-S4 (red) and GLORYS (black) ocean initial conditions.



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C. Prodhomme (IC3)

Initialization: in-house sea ice reconstructions

- NEMO3.2 ocean model + LIM2 sea ice model
- Forcings: 1958-2006 DFS4.3 or 1979-2013 ERA-interim
- Nudging: T and S toward ORAS4, timescales = 360 days below 800m, and 10 days above except in the mixed layer, except at the equator (1°S-1°N), SST & SSS restoring (-40W/m2, -150 mm/day/psu)
- Wind perturbations + 5-member ORAS4 -> 5 members for sea ice reconstruction

➡ 5 member sea ice reconstruction for 1958-present consistent with ocean and atmosphere states used for initialization

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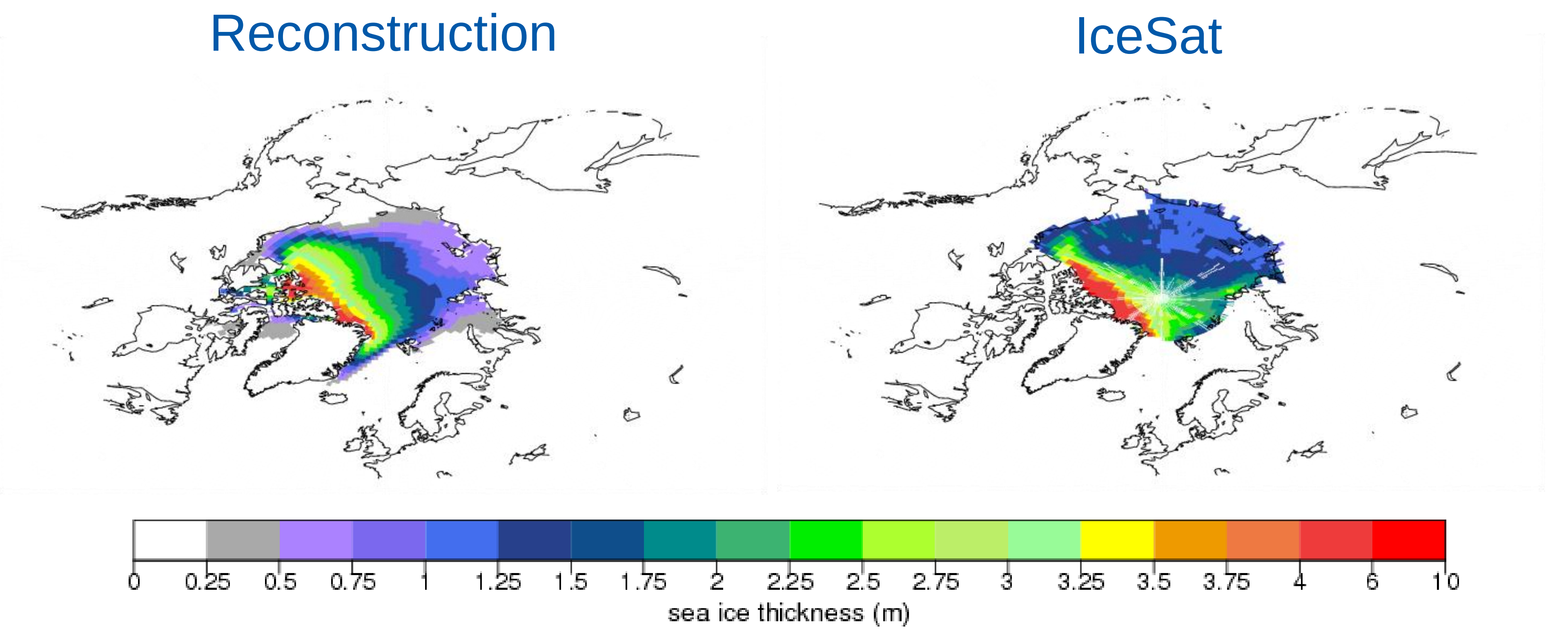
Guemas et al (2014) Climate Dynamics

Initialization: in-house sea ice reconstructions

2003-2007 October-November Arctic sea ice thickness



Too much ice in central Arctic, too few in the Chukchi and East Siberian Seas

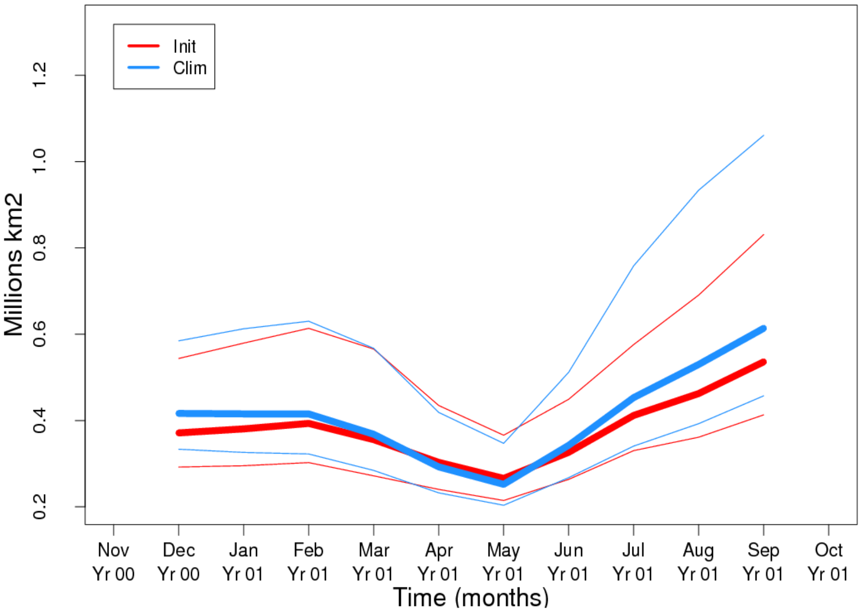
Guemas et al (2014) Climate Dynamics

Impact of sea-ice initialisation

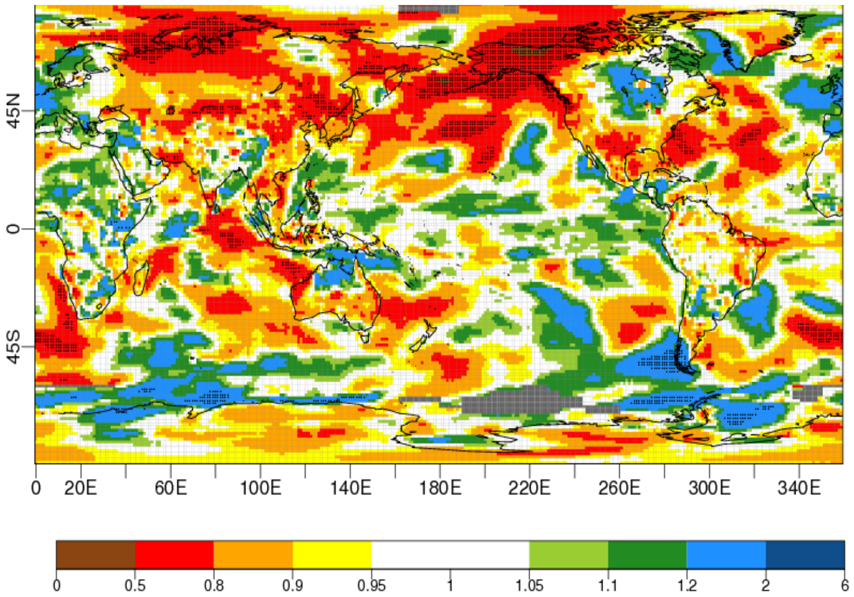
Predictions with EC-Earth2.3 started every November over 1979-2010 with ERAInt and ORAS4 initial conditions, and a sea-ice reconstruction. Two sets, one initialised with realistic and another one with climatological sea-ice initial conditions.

Substantial reduction of temperature RMSE in the northern high latitudes when using realistic sea-ice initialisation.

RMSE Arctic sea-ice area



Ratio RMSE Init/Clim hindcasts 2-metre temperature (months 2-4)



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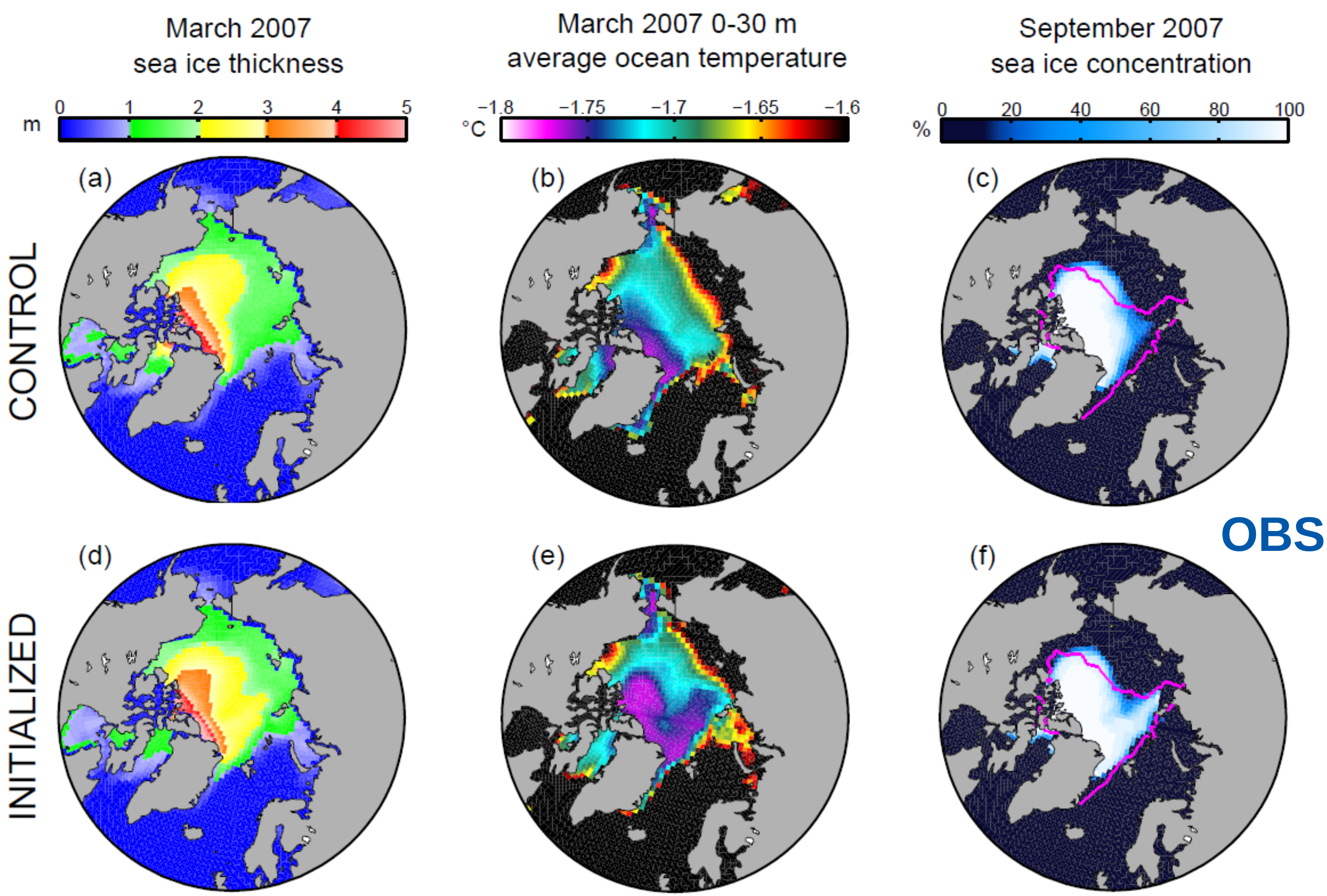
Guemas et al. (2014)

Initialization: sea-ice data assimilation

Relevance of multivariate initialization for sea-ice prediction



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Francois Massonnet (IC3)

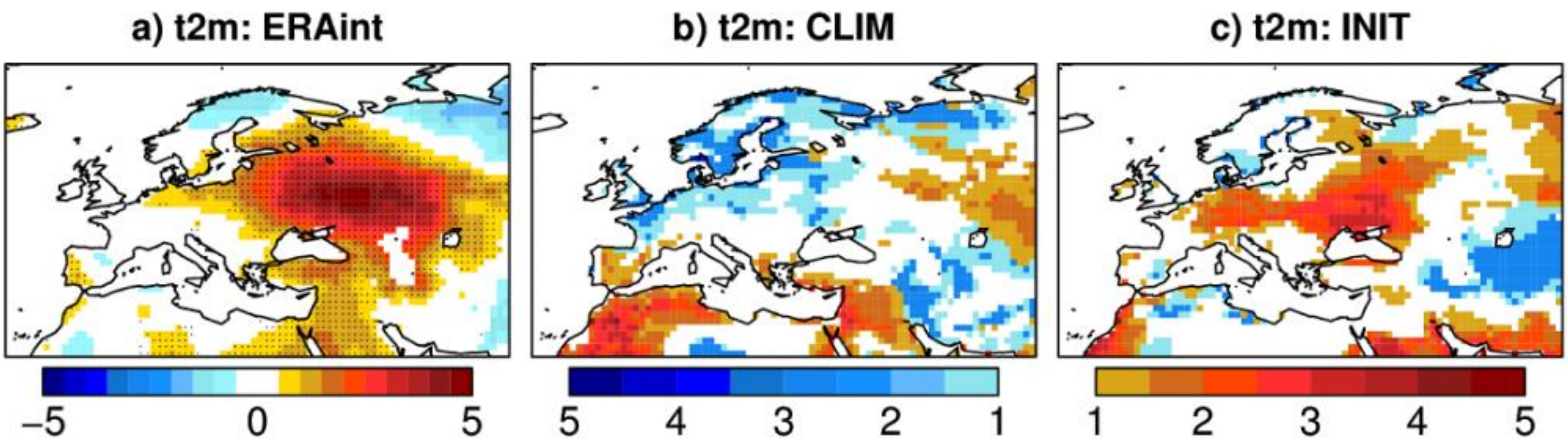
Initialization: sea-ice data assimilation

Fully-coupled sea-ice data assimilation in EC-Earth: the next challenge

- What are the perturbations required to generate adequate spread in EC-Earth during the forecast steps of the assimilation run?
- Should the atmosphere be updated when sea-ice observations are assimilated?
- Can we afford to run the EnKF with less members (CPU time limits)?

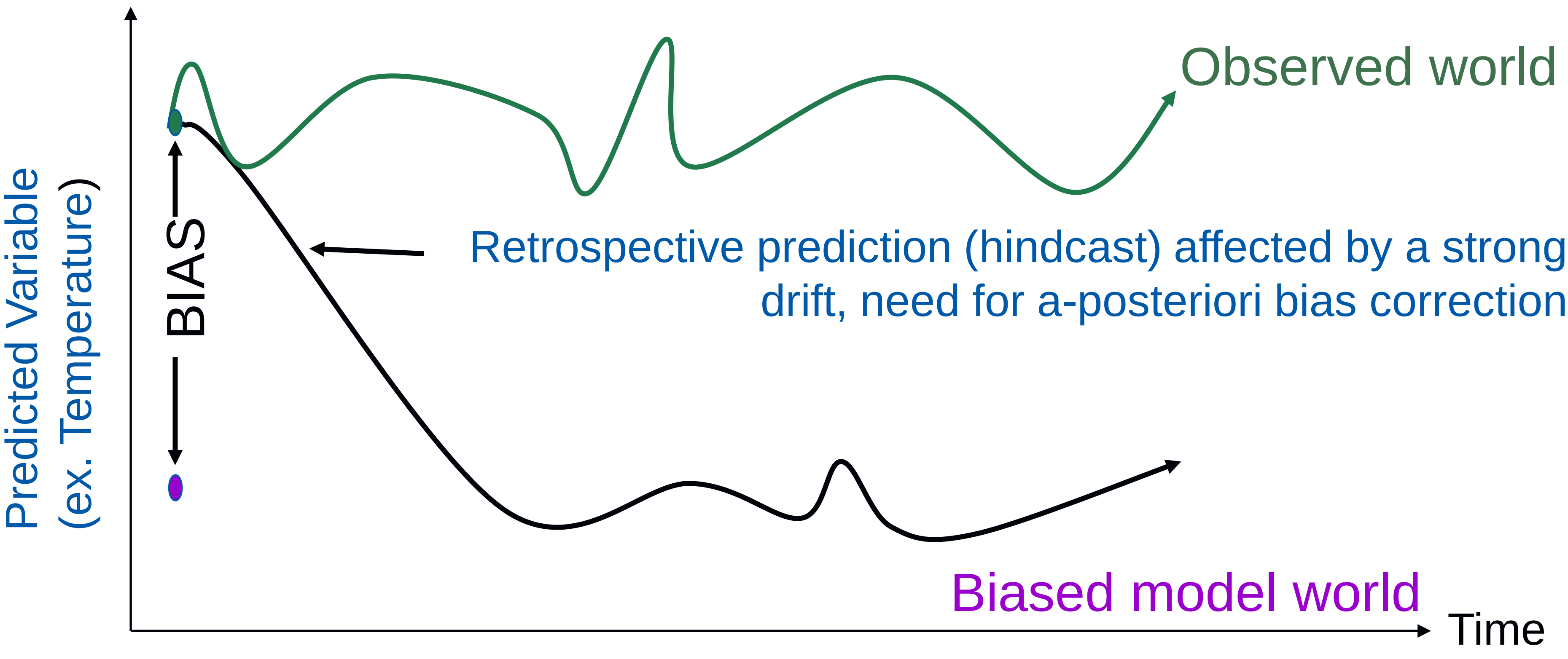
Impact of land-surface initialization

JJA precipitation in 2003 (top row) and near-surface temperature in 2010 (bottom row) anomalies from ERAInt (left) and experiments with a climatological (centre) and a realistic (right) land-surface initialisation. Results for EC-Earth2.3 started in May with initial conditions from ERAInt, ORAS4 and a sea-ice reconstruction over 1979-2010.



Prodhomme et al (2015) Climate Dynamics

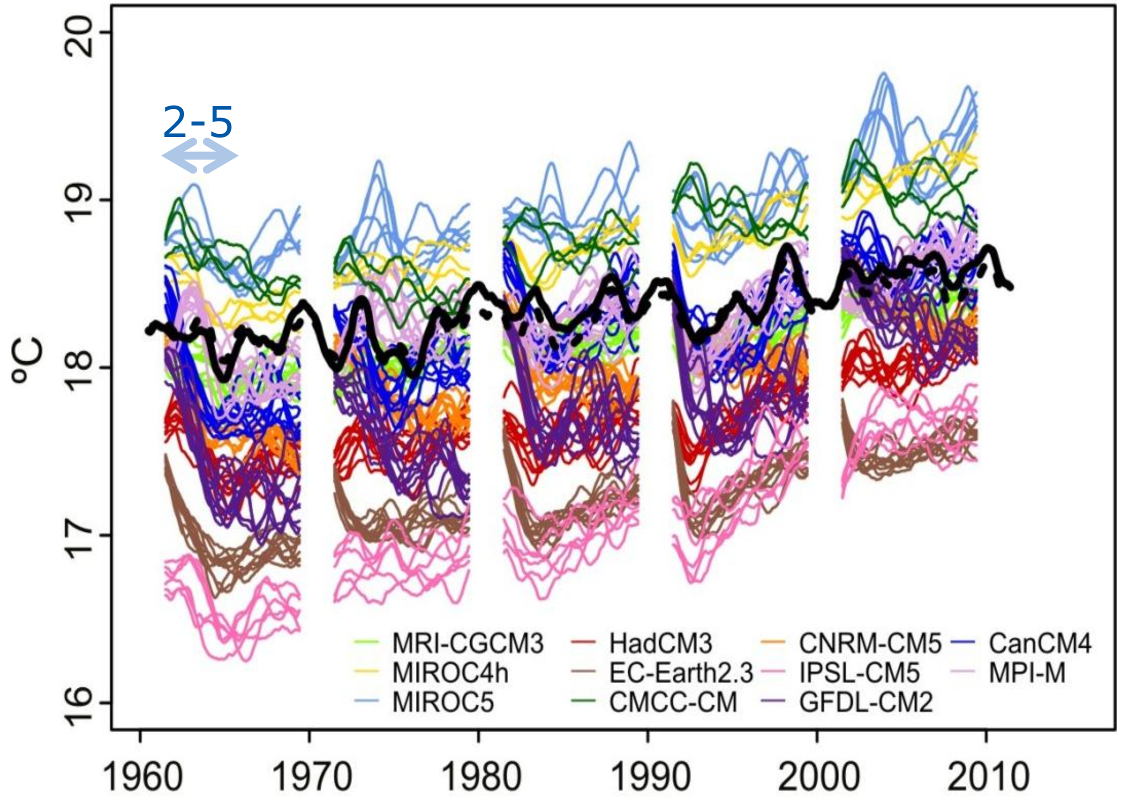
The climate prediction drift issue



The climate prediction drift issue

Global mean near-surface air temperature over the ocean (one-year running mean applied) from CMIP5 hindcasts. Each system is shown with a different colour. NCEP and ERA40/Int used as reference.

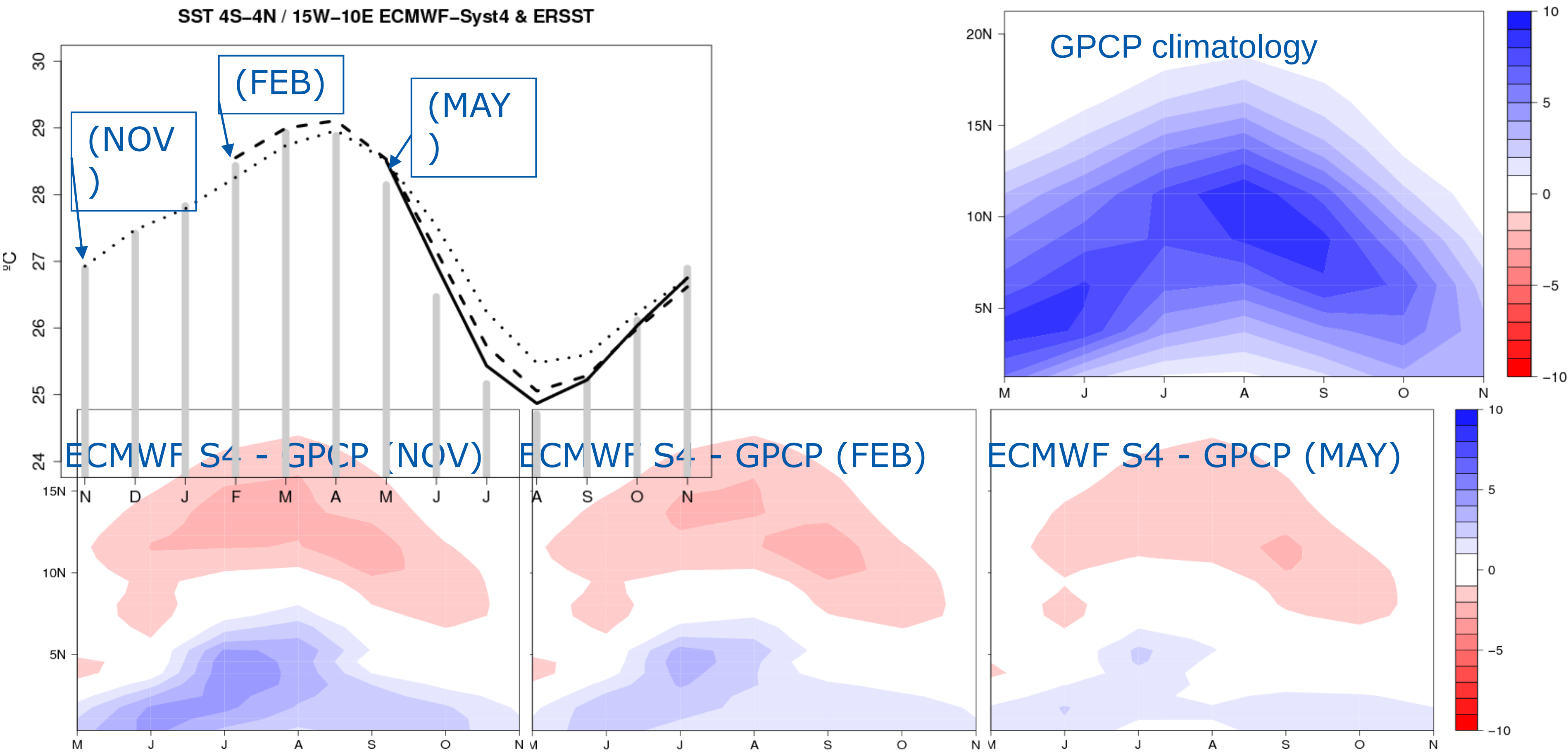
Examples of shock, drift and large systematic error can be found.



IPCC AR5 WGI (2013)

The climate prediction drift issue

Averaged precipitation over 10ºW-10ºE for 1982-2008 for GPCP (climatology) and ECMWF System 4 (systematic error) with start dates November (6-month lead time), February (3) and May (0).



Doblas-Reyes et al. (2013)

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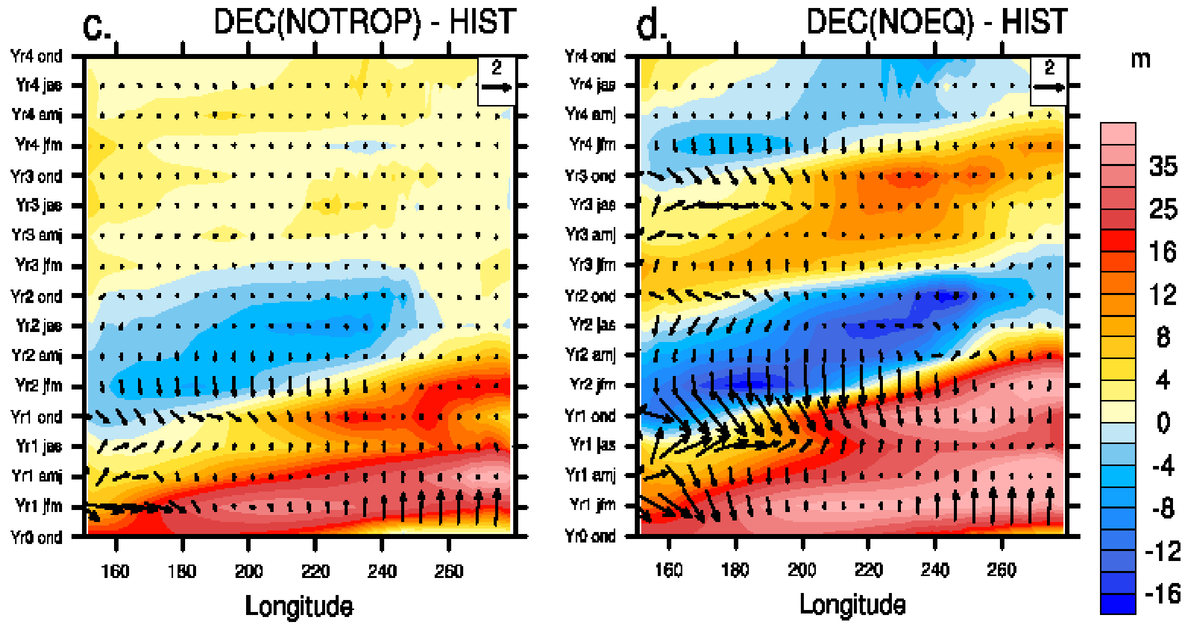
Origins of the drift: initial imbalance

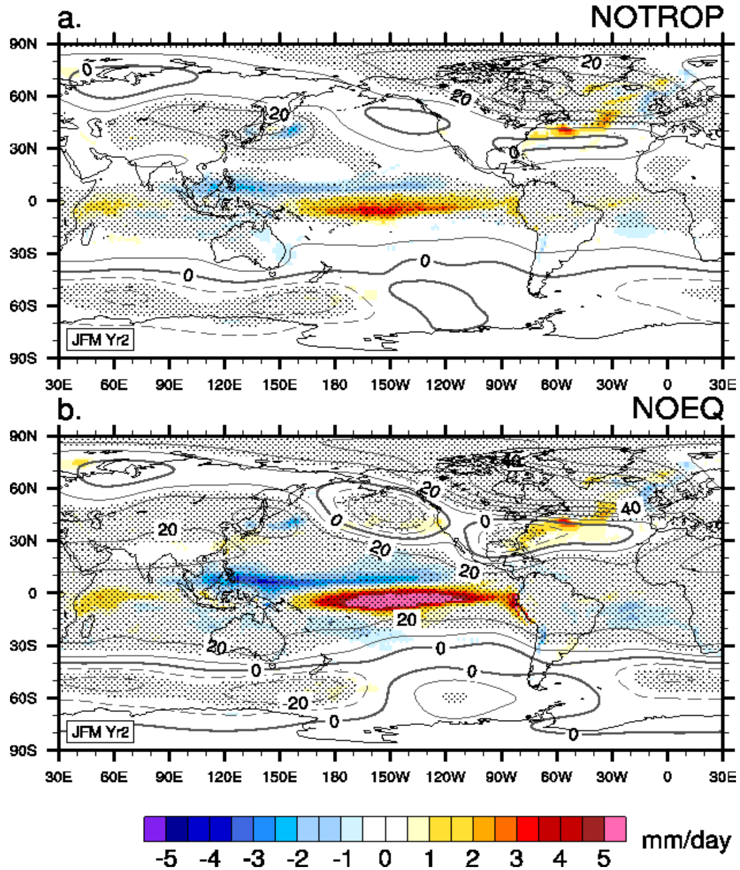
Lead-time (from OND Year 0 to OND Year 3) versus longitude for (c) DEC_NOTROP-HIST and (d) DEC_NOEQ-HIST seasonal means differences of the 20ºC isotherm depth (colours) and 10-meter winds (arrows) over 2ºS-2ºN. Contour interval every 2 metres and arrow units given in the upper-right corner (m s-1). Start dates every five years over 1960-2005. The first year of the forecasts shows a quasi-systematic excitation of ENSO warm events, an efficient way to rapidly adjust to its own mean state. This is worse in DEC_NOEQ.



Sánchez-Gómez et al. (2015)

Origins of the drift: initial imbalance

Z500 (contours) and precipitation (shading) differences between hindcasts initialised from (a) NOTROP_IC and (b) from NOEQ_IC, and HIST at forecast time JFM Year2. Grey hatching stands for Z500 significance at 95%. Contour and shading intervals are 10 metres and 0.5 mm/day.



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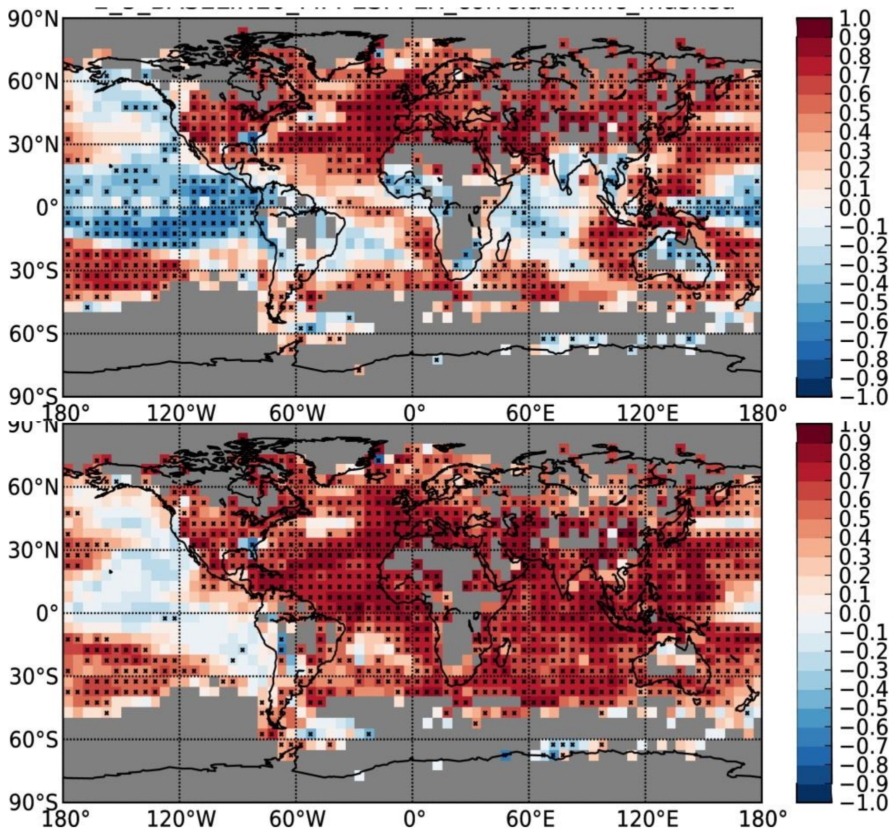
Sánchez-Gómez et al. (2015)

Origins of the drift: spurious trends in the ics

Correlation of the ensemble mean 2-5 year hindcasts of surface temperature performed with the MPI-OM system over 1961-2012 using (top) CMIP5 (ocean forced with NCEP/NCAR reanalysis) and (bottom) MiKlip (nudging towards ORAS4) initial conditions. Change in the negative skill over the tropical Pacific, even using the same climate model.

CMIP5

MiKlip system



Pohlmann et al. (2013)

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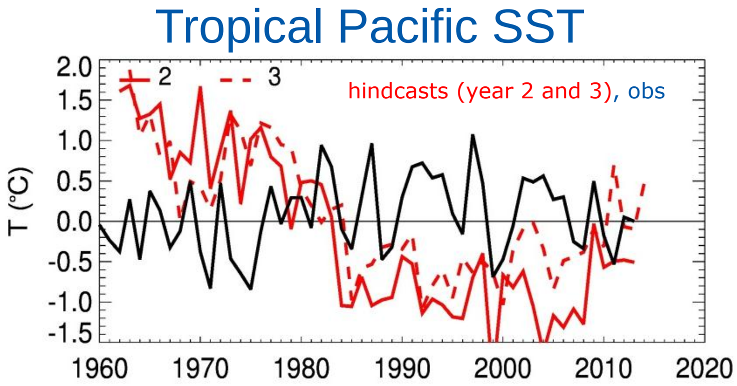
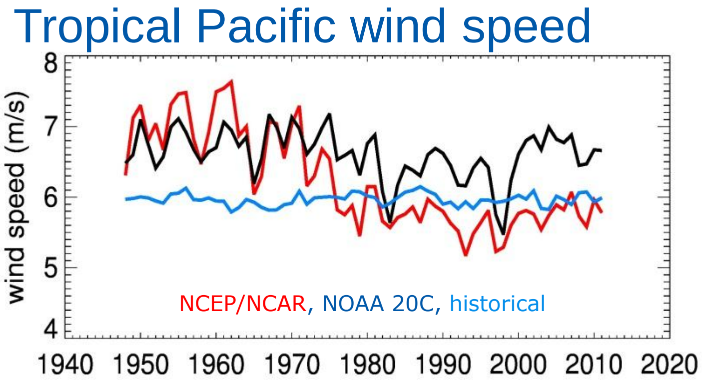
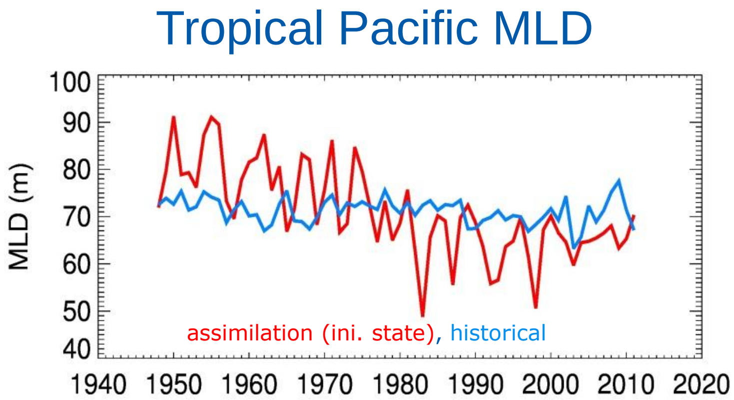
Origins of the drift: spurious trends in the ics

Hindcasts and analyses used in the MPI-OM system for CMIP5 (ocean forced with NCEP/NCAR reanalysis). Suspicious trend in NCEP/NCAR winds leading to trend in mixed layer depth.







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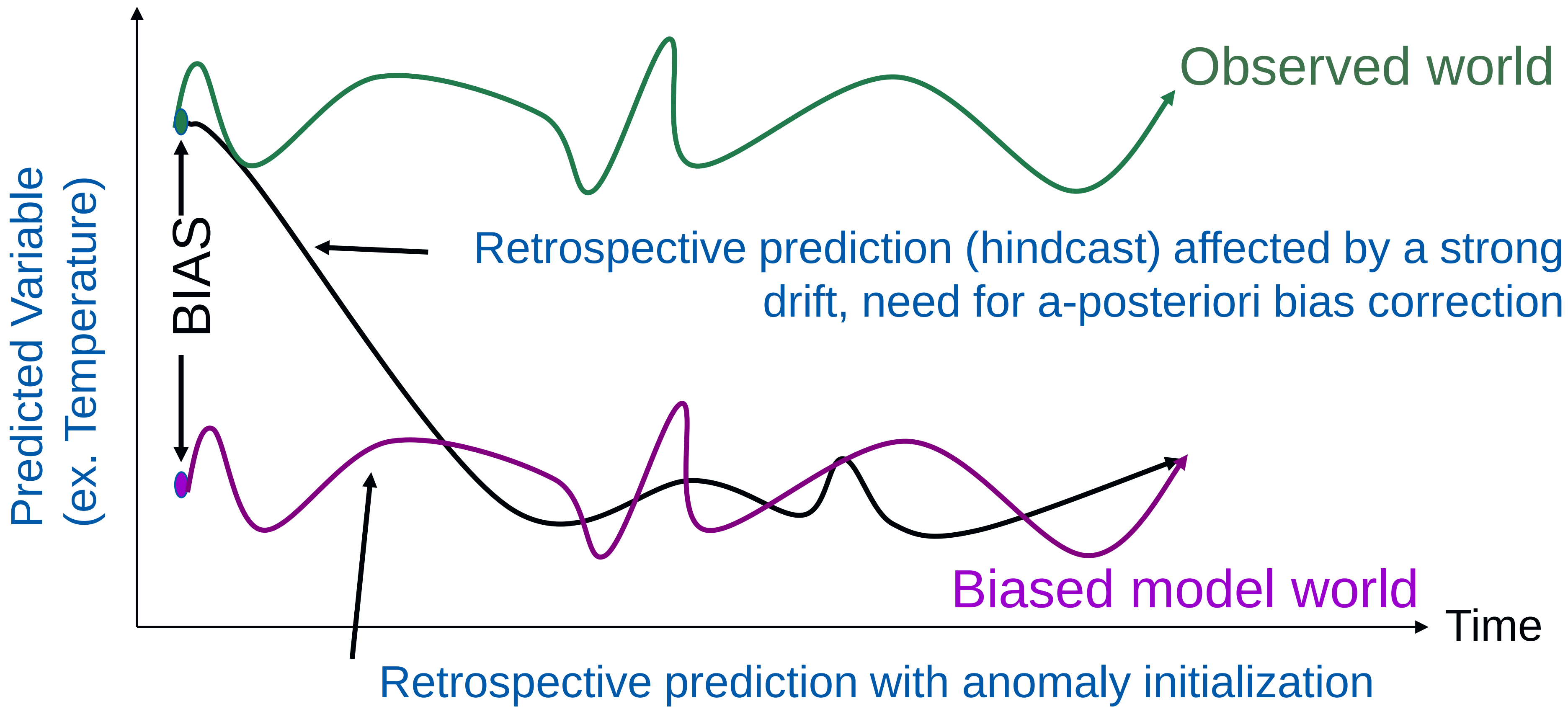
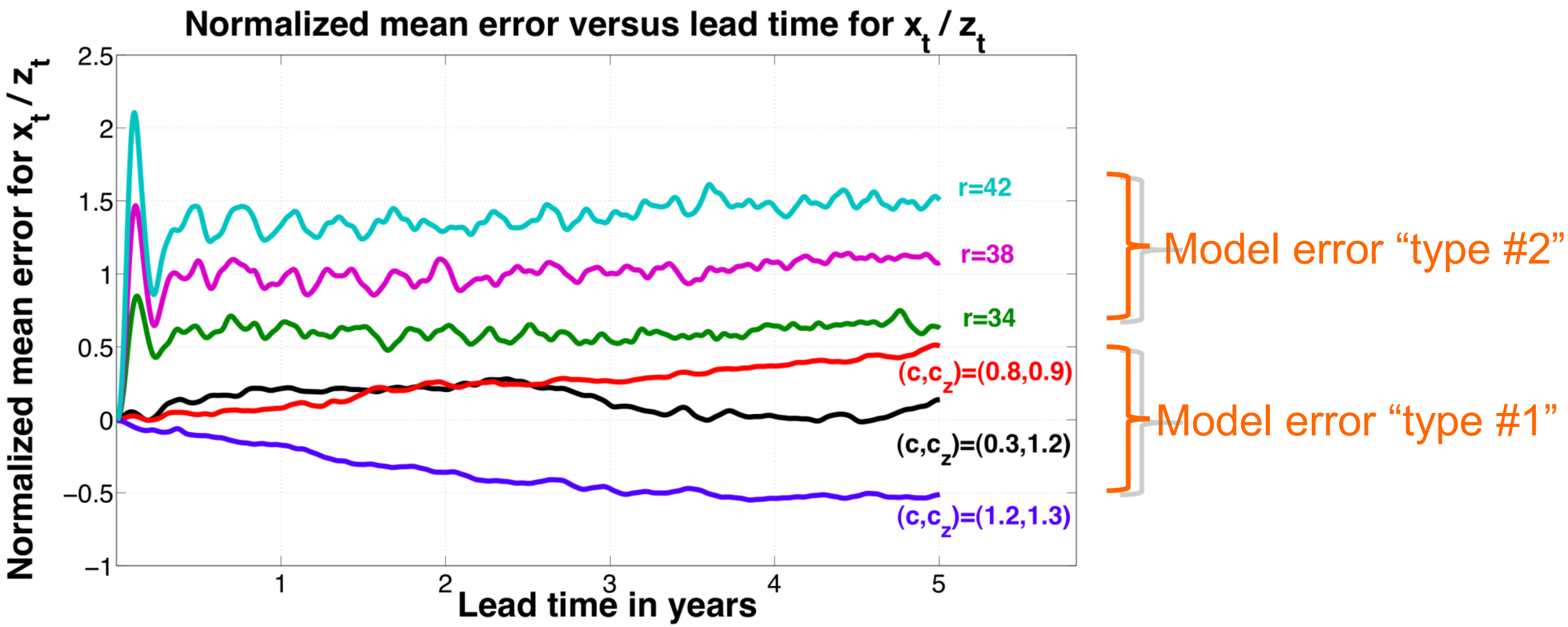
Pohlmann et al. (2013)

The climate prediction drift issue



Initialization approaches: FFI and AI

Mean error of two variables from 360 decadal predictions performed with the Lorenz model with three compartments (ocean, tropical atmosphere and extra-tropical atmosphere). The configurations where AI outperforms FFI are associated with a strong initial shock and a larger bias.



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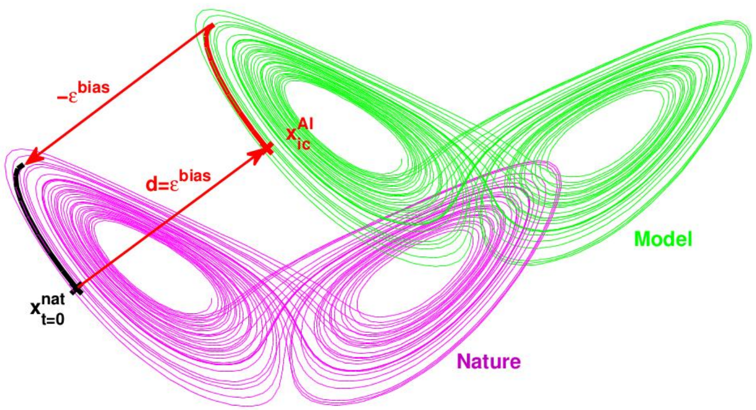
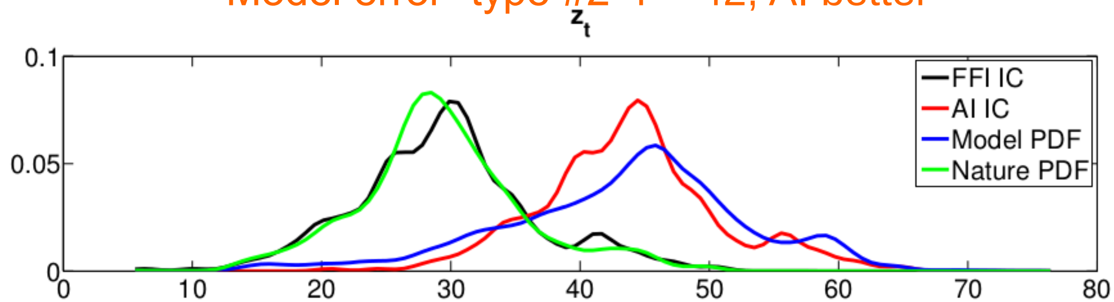
Carrassi et al. (2014)

Initialization approaches: FFI and AI

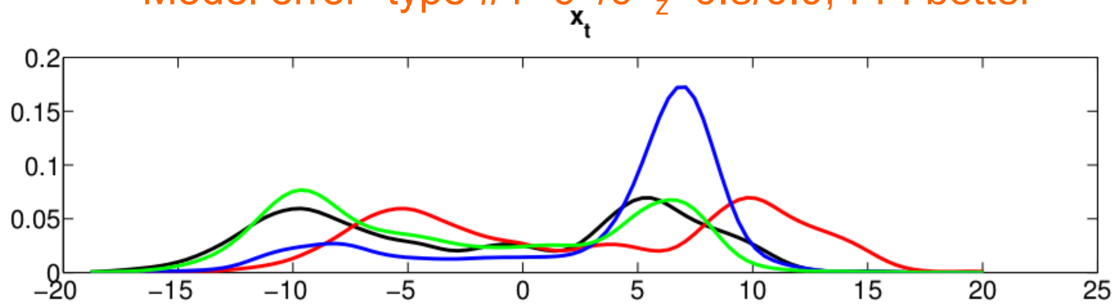
PDFs of initial conditions (black and red) and of the model and "nature" climatologies (blue and green) for the Peña and Kalnay model with three compartments (ocean, tropical atmosphere and extra-tropical atmosphere).



Model error "type #2" r^m=42, AI better



Model error "type #1" c^m/c^m_z=0.8/0.9, FFI better



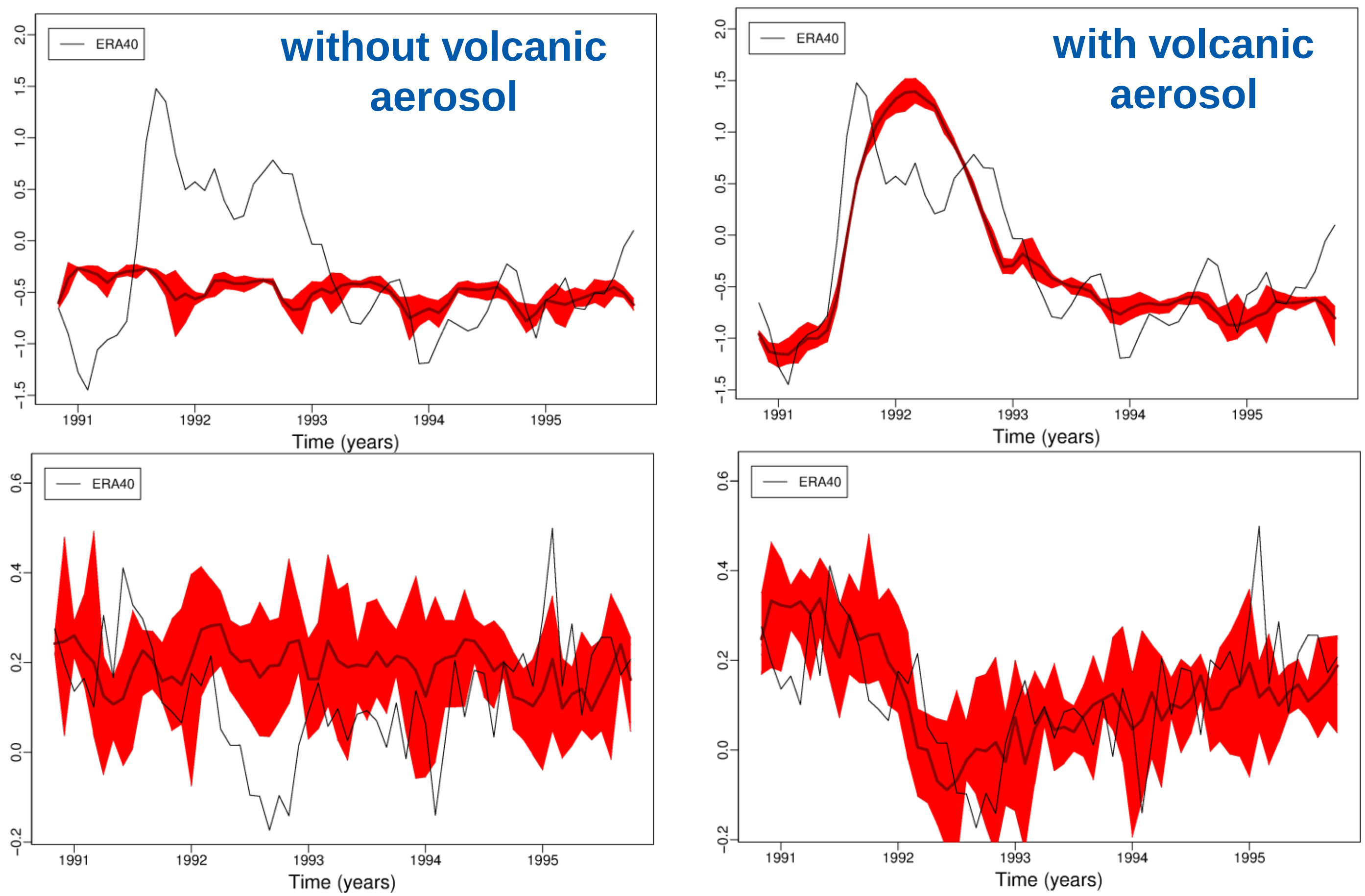
Weber et al. (2015)

Volcanic aerosol

EC-Earth2.3 simulations of volcanic aerosol impact for Pinatubo. Five-member ensembles initialised on the 1 November 1990. **No consistent treatment of volcanic aerosol and ozone**.

T50

Near-surface air temperature



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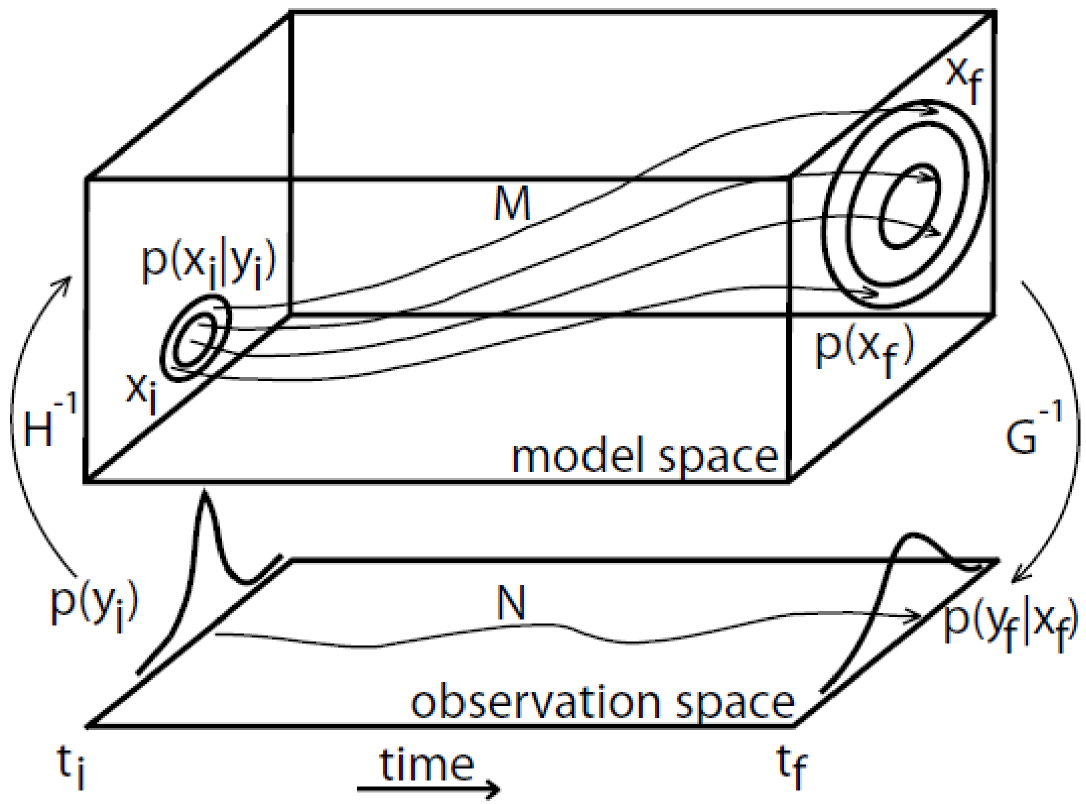
M.. Ménégoz (IC3)

Calibration

Forecast assimilation: y for observations and x for model output.



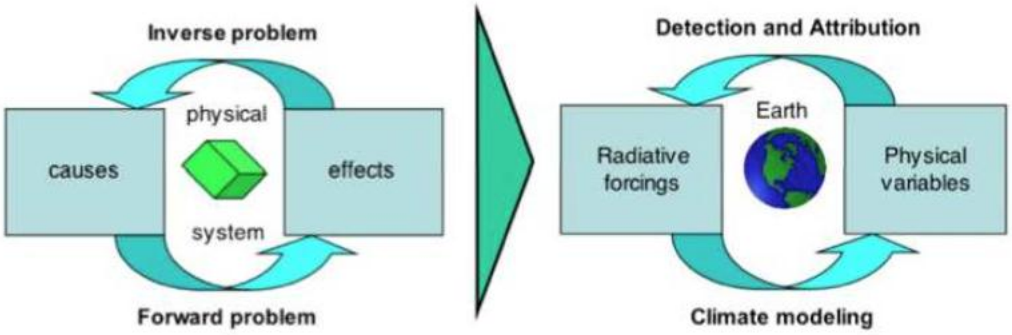
Stephenson et al. (2015, Tellus A)

Some new challenges: atmospheric composition

- MERRA2, joint atmospheric and aerosol reanalysis (MERRA is the most used reanalysis by the wind-energy sector)
  - Updated model and data assimilation system since MERRA
  - Updated aerosol emissions
  - Aerosol assimilation: AVHRR up to 2001, MODIS, MISR and AERONET
  - Global, high temporal frequency atmosphere and aerosol output: 0.5° x 0.625°, 72 vertical levels, 1979-present
  - Progression of 4 parallel MERRA-2 production streams with projected availability by Q2 2015
- Dust reanalyses, challenges: soil moisture, dynamic vegetation, land use, capture of convective downdrafts, current assimilation activities still use AOD while vertical structure is critical for long-range transport; in general PM2.5 determination difficult due to biases in the observing system and inconsistencies when assimilating AOD

Some new challenges: coupled DA

- Use of ESMs as the unified modelling instrument across all forecast time scales from days to decades
- Better exploit the new generation of Earth observations
- State-of-the-Art: weakly coupled DA
- New DA approaches are able to simultaneously deal with systems possessing many scales
- Non-Gaussian analysis framework: non-linearities (model, H, B) cause non-Gaussian distributions, ensemble-based (EnKF, I-EnKS Iterative Ensemble Kalman Smoother) and dynamically based (AUS, Assimilation in the Unstable Subspace) methods as solutions
- DA for D&A



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An interesting, far from NWP, look at climate prediction

- Johanna Baehr (Univ. Hamburg)
- The vision would be that we have an earth system model, and with that
  - a long control simulation (stable climate)
  - historical simulations
  - coupled assimilation
  - ensemble generation within the assimilation method
  - possibility to run the same model in forecast mode (for however many months)
- All the different things can then be addressed in that model:
  - reducing model bias
  - improving initialization (assimilation/ensemble generation)
  - careful bias correction (and drift)
  - identify 'data gaps' (where do we need more observations?).

Some comments

- Climate services require the best reanalysis information: initialisation, ensemble generation, calibration, chemistry, etc.
- The concept of environmental forecasting is just starting to be adopted.
- The best reanalysis is not necessarily the best way to initialize a system. The initial conditions need to be adapted to the forecast system. A reanalysis of the reanalysis?
- Appropriate reanalyses (all components) are needed to undertake environmental forecasting, including forecast calibration.
- Ensemble generation is an open issue and directly linked to the initialization.
- Climate modelling requires efficient use of HPC, and progress in Big Data (storage and analytics).